U. S. DEPARTMENT OF AGRICULTURE

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CLOVER FAILURE

A STAND OF RED CLOVER has been increasingly difficult to secure for some years in many sections.

This has resulted in most of the clover belt in a decline in the acreage in clover as compared with that in cereals.

Clover is the best legume to grow in rotation with small-grain and hoed crops, but only a small percentage of improved land is in clover.

The causes of clover failure are to be sought in improper soil conditions, in diseases, in the use of nonadapted seed or in improper methods of seeding, and in the use of harmful nurse crops.

Improper soil conditions result from constant cultivation and the consequent loss of lime, phosphates, potash, and organic matter, making the soil unsuited to the growth of clover.

Such conditions can be remedied by applying the elements lacking in a field and by working in manure and other forms of organic matter.

In some cases clover failure is due to diseases, and then a disease-resistant variety must be used if available, or some other legume substituted for red clover.

Alsike clover, hairy vetch, or annual summer legumes, such as soy beans, should be used when for any reason land that needs lime can not be economically limed.

When red clover fails on land well supplied with lime, sweet clover can often be substituted to advantage.

CLOVER FAILURE.

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CONTENTS.

INTRODUCTION.

WHY RED CLOVER, that once flourished so luxuriantly, is often a failure now has been a subject of great interest for many years. Why is it so hard to get and to maintain a good stand? The question is important because red clover is the key crop in any rational rotation system in much of the agricultural region of this country. The benefits to be derived from the regular use of a legume in the rotation have been so often pointed out that they no longer need to be emphasized, and of all legumes at present known red clover is by all odds the best fitted for use in the 3-year and 4-year rotations popular in the northeastern quarter of the United States. The steadily increasing concern over clover failure emphasizes this fact. Farmers want to grow clover; they realize its importance and fear the effect which lack of it may have on the yields of other crops. However, as will be more clearly pointed out later, one reason why clover fails is because farmers have so generally lacked appreciation of the needs of the plant and have taken it for granted that clover ought to grow anywhere if only any kind of clover seed were thrown on the ground in any way, however careless. While it is true that on new land clover will commonly grow well with little attention, this condition passed away when the land became worn from continued and unwise cropping, and red clover was the first crop to show the effect of the change in the condition of the soil. Nevertheless, the old methods of seeding were continued, failures became more frequent, and after a time the farmer often abandoned the attempt to grow clover at all. In many of these cases good clover crops would have been secured if half as much effort had been put into getting a stand of clover as has been frequently expended in the Eastern States to get a stand of alfalfa.

RED CLOVER COMPARED WITH AN ANNUAL LEGUME.

It is true that other legumes may be used in a rotation with corn and small grain, but where red clover thrives no other legume is as convenient and economical for the production of hay and for soil improvement at the same time. While an exact comparison between red clover and an annual legume like soy beans can not be made because the data on which to base such a comparison are imperfect, it is possible to make a general comparison so as to illustrate the statement just made.

There is considerable information about the relative weight of tops and roots in red clover and about the nitrogen content of tops and roots, but there is little information of that sort about soy beans. The Delaware Agricultural Experiment Station[1] some years ago determined the weights of tops and roots of both red clover and soy beans. It was found that in soy beans 90 per cent of the weight was in the tops and 10 per cent in the roots, while in red clover 70 per cent was in the tops and 30 per cent in the roots. Both crops may be expected to yield 2 tons of hay each, in which case there would be left 450 pounds of roots in the soil of the soy-bean field and 1,700 pounds in the soil of the red-clover field. The Delaware station found, further, that the soy-bean roots contained 1.22 per cent of nitrogen and the clover roots 2.48 per cent. At this rate the soy beans would leave 5.5 pounds of nitrogen in the soil and the clover roots 46.5 pounds. While legumes take nitrogen from the air, they also take some from the soil, and a plant with relatively heavy top growth will leave the soil poorer in nitrogen if the hay is removed. Red clover, on the other hand, may leave the soil richer in nitrogen even if the hay is removed, and if the second growth is turned under there will be a very material increase in potential nitrates.

The above comparison has been made not to criticize the use of soy beans, which are an excellent crop to grow when clover can not be grown, but to point out that when clover can be grown an annual legume will not serve as well for a combined hay crop and soil improver. In this respect red clover occupies a well-nigh unique position.

DECLINE OF CLOVER CULTURE.

That the decline in red-clover culture is no myth becomes abundantly evident when one reads the agricultural literature of the past 40 years. Letters from farmers to the agricultural press and articles by farmers and by experiment-station workers in the press all express concern regarding this condition and offer various reasons and remedies. Owing to the incompleteness of the Federal and State statistics of agriculture it is difficult to illustrate the decline in red-clover culture by actual figures. However, some data bearing on the subject are available, and in Figure 1 there is shown the relation between the acreage reported as being in cereals and in clover alone, according to the census figures for 1900, 1910, and 1920. A study of this graph will show that, though the acreage in clover was a little larger in

[1] Penny, Charles L. Cover crops as green manure. Del. Agr. Exp. Sta. Bul. 60, 44 p. 1903.

1919 than in 1909, it was lower than it was in 1899, while in the heart of the clover area the acreage in cereals was greater in 1919 than in 1899. It is not possible to make comparisons with the acreage before 1899, as no clover figures are included in the earlier census statistics. A great deal of clover is seeded with timothy, but no data on the timothy and clover acreage were taken before 1909. When it is remembered that since the troubles with red clover became acute a considerable substitution of alsike and sweet clover for red clover has taken place and that the census figures include all clovers, it will be at once evident that the decline in the acreage of red clover must be even greater than would appear from the figures.

TABLE 1.—*Percentage of the acreage in all tame hay that was in clover alone in 1899, 1909, and 1919.*

Section.	1899	1909	1919
	Per cent.	*Per cent.*	*Per cent.*
New England States	0.47	0.43	0.76
Middle A tlantic States	5.3	1.98	2.69
Delaware, Maryland, Virginia, and West Virginia	13.67	5.8	8.33
Kentucky and Tennessee	21.38	14.9	14.66
East North-Central States	17.68	8.78	10.45
Minnesota, Iowa, and Missouri	7.16	4.91	7.43

The decline in the acreage of red clover may also be shown by comparing the acreage in pure clover hay with that in all tame hay, remembering that an unknown quantity of this pure clover hay is

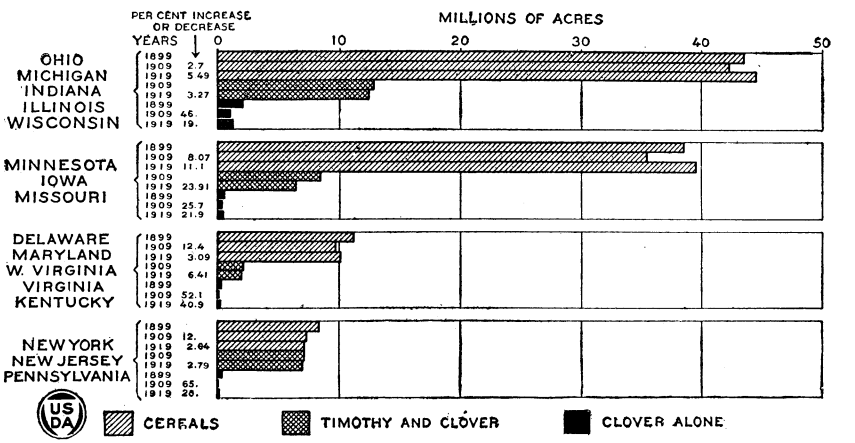

FIG. 1.—Diagram showing the relation between the acreage in all cereals and that in clover alone and in timothy and clover in four groups of States in the United States in 1899, 1909, and 1919.

alsike clover. Table 1 shows the percentage of the acreage in all tame hay that was in clover alone in 1899, 1909, and 1919. This table shows that the culture of clover declined as compared with that of other tame-hay crops. This decline was most marked between 1899 and 1909. Some recovery took place between 1909 and 1919, but except in the extreme east and the extreme west of the clover region this recovery did not restore the relations obtaining in 1899.

HOW MUCH OF THE CROPPED LAND SHOULD BE IN CLOVER?

There are no data from which a certain answer may be given to this question. It is necessarily a matter of opinion. If the 4-year rotation of the East is taken as a fair standard, then 25 per cent of the cropped land should be in clover each year. With a 3-year rotation this percentage would be increased and with a 5-year rotation decreased. The Illinois Agricultural Experiment Station has stated that growing clover on something like one-quarter of the tillable land is absolutely essential.

The Michigan station considers an ideal condition to be that in which 33 per cent of the cultivated land on lighter soils and 25 per cent on the heavier soils is devoted to some legume.

It is the general opinion of competent men that from 20 to 25 per cent of the land should be in a legume every year. As pointed out, however, while a crop like soy beans is a good one where clover can not be grown, the effect on the land will not be as good when soy beans are grown and harvested for hay as when red clover is grown and one crop harvested for hay.

TABLE 2.—*Percentage of improved land in clover alone, from reports of the United States census for 1900, 1910, and 1920.*

Section.	1900	1910	1920
	Per cent.	*Per cent.*	*Per cent.*
New England States	0.23	0.21	0.40
Middle Atlantic States	1.48	.54	.80
Delaware, Maryland, Virginia, and West Virginia	1.12	.54	.66
Kentucky and Tennessee	1.09	1.07	1.38
East North-Central States	2.52	1.31	1.59
Minnesota, Iowa, and Missouri	.85	.60	.72

An inspection of the figures in Table 2 will show how far from filling the above requirement is the acreage actually in clover. A larger acreage than that in clover alone is, of course, in clover and timothy, but even if half this acreage is taken to be clover, the total acreage of improved land in clover, except in the New England and Middle Atlantic States, will nowhere exceed 10 per cent.

TABLE 3.—*Percentage of acreage of all harvested crops in timothy and clover and in clover alone in 1919.*

Section.	Timothy and clover.	Clover alone.
	Per cent.	*Per cent.*
New England States	39.0	0.52
Middle Atlantic States	26.0	1.1
Delaware, Maryland, Virginia, and West Virginia	8.0	1.35
Kentucky and Tennessee	3.13	2.3
East North-Central States	9.5	2.0
Minnesota, Iowa, and Missouri	6.2	.97

If a comparison is made between the acreage in clover alone and that in harvested crops rather than that in improved land, the conditions seem slightly more favorable, especially if half the timothy and clover acreage be included. However, even including half the

timothy and clover in the clover acreage, it will appear from Table 3 that in the main part of the corn-clover belt only 2 to 6 per cent of the land in harvested crops was in clover of any kind in 1919.

CLOVER FAILURE DEFINED.

The conditions briefly outlined have not arisen as a result of any one cause; there are several causes for clover failure, some operating more strongly in one part of the country, some in another. By clover failure is understood the complete or partial loss of a stand of red clover or the failure to secure a stand after seeding. When a clover meadow produces half a ton of clover hay instead of the 2 or 3 tons it should produce, this condition is one of partial failure. If many plants had not perished there would have been more hay. The more extreme forms of failure have been often described as due to "clover sickness," this term being used to denote a soil condition. It has been thought that the soil became "sick of clover." Various theories have been advanced both in Europe and in America to account for this condition, one writer even going so far as to suggest that the excreta of insects poisoned the soil. Others have thought that perhaps toxins were excreted by the clover plant itself and that these resulted in the soil condition called "clover sickness." There is no evidence of the correctness of any of these theories. The soil does not become "sick of clover," but the clover itself may become sick, as indeed it does when attacked by specific diseases or when the soil conditions are not suited to its growth. It is now recognized that there is nothing mysterious about clover failure. Clover fails either because the soil is unsuited to its development, because it is attacked by a fungus or by an insect or a nematode, or because of the use of seed of strains not adapted to the climatic conditions prevailing in the United States. In the following pages, therefore, the term clover failure will be used, and the term "clover sickness" will be discarded as being too closely related to untenable theories to be useful.

CAUSES OF CLOVER FAILURE.

The causes of clover failure may be listed as follows:

Unsuitable soil conditions.
Unadapted or poor seed.
Poor methods of seeding.
Diseases and insects.
Wrong fall treatment the first year.

Local and unusual conditions, such as floods and unusual droughts, are, of course, not included. These can not be prevented, though it will be found that well-nourished vigorous young clover plants will not succumb as readily to drought as the weak plants growing under unsuitable soil conditions.

SOIL CONDITIONS.

Barring destructive insects and fungous diseases, plants will thrive when soil, temperature, and moisture conditions are favorable. Temperature and moisture are beyond human control in the clover belt, but they are generally favorable and by themselves rarely cause a failure of clover. Soils change with use and, especially if used unwisely, may change for the worse. Cropping alone removes from

the soil certain quantities of lime, nitrogen, phosphorus, potash, and organic matter, not to mention several minor elements, and additional amounts of some of these are lost by leaching. Cultivation favors the destruction of organic matter, and unless this is replaced the soil becomes less fit for plant growth; clay soils become less friable and sandy soils dry out faster. Such soils bake on drying; silts especially are likely to become hard, so that young clover plants have very little chance to get a start. As is well known, all plants need certain food elements, and of these nitrogen, phosphorus, and potash are commonly used in fertilizers. Lime is also a necessary food element as well as a soil amendment.

Favorable soil conditions, therefore, are those in which a soil in good tilth by reason of its organic-matter content is well supplied with lime, nitrogen, phosphates, potash, and other necessary elements. The growth of a plant on any soil in any location is an index of the favorableness or unfavorableness of the sum total of soil, temperature, and moisture conditions. Clover can dispense with nitrogen in the soil better than nonlegumes, since it can draw on the atmosphere for its nitrogen, but unless lime, phosphates, and potash are available, clover can not thrive.

DRAINAGE.

Good drainage is of first importance. Red clover will not thrive on poorly drained land. This fact has been pointed out repeatedly by more than one agricultural experiment station. Without adequate drainage the lime and fertilizers applied will be largely wasted so far as helping red clover is concerned, for the water-logged condition of the soil then becomes the limiting factor.

LIME.

Lime is a necessary food element, and it also corrects a soil condition known as "acidity." Some authorities hold that the rôle of lime as a source of plant food is the most important; others that its greatest use is as a soil amendment. Much has been written by agricultural experiment-station workers about the action of lime in the soil, but it is sufficient to point out here that, whatever may be the exact rôle of lime, there is a soil condition commonly known as "acidity" and that lime has been found effective in correcting this condition. This condition of "acidity" occurs most frequently on soils not of limestone origin, but there are also limestone soils that by long cultivation, have lost the lime in the surface soil and need lime to grow clover. The Illinois station found that 780 pounds of calcium carbonate had been lost by leaching every year for 10 years. The Pennsylvania station found that on certain plats the annual loss of lime by leaching alone was 750 pounds. Besides this, crops remove some lime, and there is therefore a steady loss of lime from all cropped lands.

With few exceptions legumes require plenty of lime, and red clover is one of the three hay plants (red clover, alfalfa, and sweet clover) used in the United States which is especially sensitive to a lack of lime in the soil. Not only does it remove relatively large quantities of lime per ton of hay, but it can not get the lime it needs as readily as can such crops as rye and buckwheat.

The work of various agricultural experiment stations has shown that lime is lost by leaching and removed by crops and that consequently cultivated lands tend to lose lime. Red clover does well on new land, but as the years pass the lime in the soil is lost and success with red clover becomes less frequent. The evidence for this statement rests not on direct experiment in which the lime has been removed from the soil until clover would not grow but on hundreds of experiments made by experiment-station workers and by farmers, which show that red clover can be grown again when lime is added to soils that are known to have lost much of their lime or that were always poor in lime and on which red-clover failures were common. The Pennsylvania Agricultural Experiment Station[2] has shown that in the same field some areas on which clover grew well had plenty of lime while others on which clover failed lacked lime. The experience of the Ohio Agricultural Experiment Station is described in the following words:[3]

For a number of years it has been increasingly difficult to secure a crop of clover on the experiment-station farm. The seed germinates and at first the stand appears to be good, but when the wheat is taken off the growth of clover is found to be uneven, there being patches of good clover interspersed with

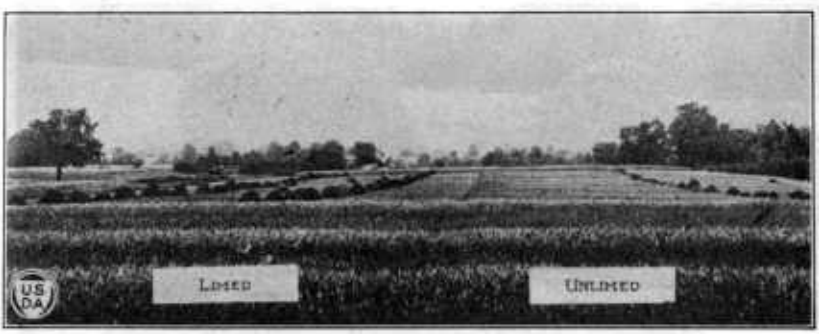

FIG. 2.—Clover on limed and unlimed portions of Wooster field, Ohio. (Illustration supplied by the Ohio Agricultural Experiment Station.)

areas on which the plants are stunted. These areas increase in size as the season progresses; the clover on them is largely destroyed during the winter following the seeding, and by spring there is usually but little clover left.

This difficulty is not confined to the station farm, but is prevalent over a considerable part of northeastern Ohio. The soil on which this trouble is experienced is generally found to give an acid reaction under the litmus test, and the poorer the clover the more pronounced is the indication of acidity.

Again later, the same station reported:[4] "At the time the experiments described on the preceding pages were planned the deficiency in calcium had not been detected, as clover was growing luxuriantly when other fertilizing elements were furnished, but within a few years the clover crops began to fail, and in 1900 the experiment was begun of liming half the land as it was being prepared for corn, caustic lime being applied to the west ends of the plats, fertilized and unfertilized alike." The effect of liming was at once evident in the better growth of clover (figs. 2 and 3).

[2] White, J. W. Variation in the growth of clover on Mitchell field (A). *In* Pa. Agr. Exp. Sta. Ann. Rpt. 1913–14, p. 65-66, 1 pl. 1915.

[3] Thorne, Charles E. The maintenance of fertility. Liming the soil. Ohio Agr. Exp. Sta. Bul. 159, p. 165–196, illus. 1905.

[4] Anonymous. The maintenance of soil fertility. Ohio Agr. Exp. Sta. Bul. 336, p. 577–646, illus. 1919.

It will be impossible in the limits of this bulletin to refer to all the experiments on this subject. They may be found in reports and bulletins from almost every State in which red clover is an important crop. The State agricultural experiment stations in Michigan, Pennsylvania, Ohio, Indiana, Illinois, Tennessee, and Kentucky have especially contributed to our knowledge of this subject. There is also a great volume of evidence from individual farmers who have given their experiences in the agricultural press and from county agricultural agents, who, more especially in recent years, have reported on demonstrations with lime for clover. Many of these reports record greatly increased yields of clover from the use of lime even when complete failure did not result on the unlimed land, while others report fair to good yields on limed land and failures on land

FIG. 3.—Clover from equal areas, limed and unlimed. (Illustration supplied by the Ohio Agricultural Experiment Station.)

not limed. Reference to some of these reports will have to stand as representative of the trend of all.

EXPERIMENT-STATION RESULTS.

The Illinois Agricultural Experiment Station reported: "To the lack of limestone in the soil are probably due more failures than can be attributed to any other soil condition."[5] On run-down clay soil in Indiana lime alone increased the yield from 1,440 to 2,920 pounds per acre.[6] In Gibson and Green Counties, Ind., the addition of lime increased the yield of clover hay more than 1,000 pounds per acre. As a result of 16 years' work on nine different fields representing various soil types, the Indiana station was ready to report in 1922

[5] Readheimer, J. E., and Burlison, W. L. The importance of clover. Causes of failure and remedies. Ill. Univ. Col. Agr. Ext. Circ. 36, 7 p., illus. 1919.
[6] Wiancko, A. T. Soils and crops. *In* Ind. Agr. Exp. Sta. 31st Ann. Rpt. 1917–18, p. 58–66, fig. 9–10. 1918.

that "three-fourths of the cultivated lands of Indiana are acid in reaction. About 25 per cent of them are so very acid that clover will fail almost every year. On another 25 per cent or more clover fails whenever the season is at all unfavorable. Only about one-third of our soils are so well supplied with lime that clover failures are seldom known. . . . It is possible by the use of lime and phosphate to insure the growth of clover on practically all of the soils of the State."[7] On some of the experiment fields in Kentucky lime made the difference between success and failure. On the Berea field in Madison County the clover failed on every plat on which lime was not used, even where manure and manure and phosphates were applied. A similar result was secured at the Mayfield station, although there the unlimed fields yielded some small return.[8]

At the Hatch Agricultural Experiment Station in Massachusetts eight unfertilized plats yielded an average of 2,240 pounds of grass and clover on the limed plats and 735 pounds on those not limed.[9] The New York (Cornell) station found that lime increased the yield of clover on both fertilized and unfertilized plats.[10] The increase was in some cases as much as 100 per cent, and even then much of the yield from unlimed plats consisted of redtop. The Ohio station has repeatedly pointed out both in station bulletins and in the agricultural press that on many Ohio soils lime is essential to the growth of clover. In Ohio Bulletin No. 260 it is stated that "clover can not be grown successfully on a soil deficient in lime, and on thousands of acres in eastern Ohio clover is making a weak and sickly growth or is failing altogether because of this deficiency, and as clover fails the yields of other crops become more irregular." At this station a series of experiments was conducted with various fertilizers on clover, half of each plat being limed and the other half unlimed. The limed halves yielded increases ranging from 346 to 942 pounds per acre on the plats supplied with complete fertilizer and from 1,101 to 2,162 pounds on plats partially fertilized. When lime was added to well-manured plats the increases were 1,394 and 1,503 pounds per acre on two plats.[11] In the Pennsylvania experiments on DeKalb and Volusia soils the unlimed plats produced but few clover plants; the yield was mostly weeds. The yields on the limed plats varied from small to good, but the hay was nearly all clover.[12] In Rhode Island, where 1,400 pounds of air-slaked lime was applied per acre, clover made a good growth; without lime it was a failure.[13] In Wisconsin, mammoth clover failed entirely on unlimed land and yielded 1,906 pounds per acre on limed land.[14]

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[7] Wiancko, A. T., Walker, G. P., and Conner, S. D. The value of lime on Indiana soils. Ind. Agr. Exp. Sta. Bul. 213, 16 p., 5 fig. 1918; rev., 1922.

[8] Roberts, George, and Ewan, A. E. Report on soil experiment fields. *In* Ky. Agr. Exp. Sta. Bul. 228, p. 85-120. 1920.

[9] Gaskill, E. F. Department of agriculture. *In* Mass. Agr. Exp. Sta. 28th Ann. Rpt. [1915], p. 37a–45a. 1916.

[10] Squires, J. H. Experiments in the growth of clover on farms where it once grew but now fails. N. Y. Cornell Agr. Exp. Sta. Bul. 264, p. 345–364, fig. 58–66. 1909.

[11] Thorne, Charles E. The maintenance of fertility. Liming the soil. Ohio Agr. Exp. Sta. Bul. 159, p. 165–196, illus. 1905.

[12] White, J. W., and Holben, F. J. Soil fertility experiments on DeKalb, Volusia, and Westmoreland soils. Pa. Agr. Exp. Sta. Bul. 166, 23 p., illus. 1921.

[13] Flagg, Charles O. Report of director. *In* R. I. Agr. Exp. Sta. 8th Ann. Rpt. 1895, p. 173–192, 1 pl. 1896.

[14] Whitson, A. R., and Weir, W. W. Soil acidity and liming. Wis. Agr. Exp. Sta. Bul. 230, 32 p., 11 fig. Ed. 2, 1916.

DEMONSTRATIONS BY COUNTY AGRICULTURAL AGENTS.

The county agricultural agents, especially in New York, have been alive to the importance of lime for clover and have presented much evidence to show that lime not only increases the total yield, but that on limed land most of the hay is clover, while on the unlimed land the product is chiefly grass and weeds. The county agents' reports from New York show in some cases increases from 0.4 of a ton on the unlimed land to 2.9 tons on the limed land (Chemung County). In Jefferson County the first cutting yielded 5,920 pounds per acre on limed and 1,980 pounds on the unlimed land, while the second cut yielded 1,960 pounds on the limed and but 214 pounds on the unlimed land. In Otsego County the percentage of weeds on limed and on unlimed clover fields was determined. On limed land there was found to be between 1 and 2 per cent of weeds; on the unlimed land between 21 and 49 per cent. From Christian County, Ill., the county agent reported a 60 per cent stand of clover after liming land on which clover had failed continuously for 15 years. In all cases the reports show a satisfactory money return from the use of lime, whether or not there was total failure on the unlimed land. Scores of similar reports might be cited, but these will have to serve as examples of the vast amount of evidence that has accumulated in the past few years, all tending to show that an important factor in clover failure is the lack of lime in the soil.

Lime, then, may be considered as the first essential to clover growing on run-down soils, but it may not be and often is not the only element needed. Many of the bulletins and reports above referred to emphasize the fact that while lime was beneficial, the addition of one or more fertilizer elements greatly increased the yields. Of these fertilizer elements the most important over most of the clover belt is phosphorus.

PHOSPHORUS.

Many, perhaps most, soils in the clover belt are deficient in phosphates for the best growth of clover. Almost without exception, the State agricultural experiment stations in that section have shown the benefit of applying phosphates to clover. In some cases neither lime nor manure was of much benefit without phosphates, and in most cases, even where lime proved to be the critical element, the addition of phosphates increased yields. In Kentucky, on the Berea experiment field, where the addition of manure alone did not result in a stand of clover and manure plus lime produced only 500 pounds of clover hay per acre, the addition of acid phosphate along with manure and lime raised the yield to 2,015 pounds per acre. Similarly on the Lone Oak field, in McCracken County, the untreated plat yielded 1,168 pounds of hay per acre, manure alone increased this to 1,640 pounds, manure and acid phosphate to 1,635 pounds, and manure and lime to 2,210 pounds; but the plats to which manure, lime, and acid phosphate were added yielded 3,623 pounds per acre. On the Mayfield experiment field the no-treatment plat yielded 325 pounds per acre, the manured plat 408 pounds, manure plus acid phosphate 458 pounds, and manure plus lime 1,908 pounds; but the plats receiving manure, lime, and acid phosphate yielded 3,136 pounds

per acre. In these cases the soil evidently needed both lime and phosphate, but neither could supply the deficiency of the other and so each failed of full effect when used alone.[15]

On the Bedford field in Indiana in 1917 [16] the limed field produced 1,600 pounds of clover hay, while the one to which acid phosphate had been applied in addition to lime yielded 4,000 pounds of clover hay (fig. 4). In the experiments by the Illinois Agricultural Experiment Station phosphates more than doubled the yield of clover. Similar results have been recorded by the agricultural experiment stations of West Virginia, Ohio, Indiana, Michigan, Iowa, Missouri, New Jersey, New York, Pennsylvania, Tennessee, and Wisconsin. It is generally recognized that on many soils in the region covered

FIG. 4.—Yields of red clover, showing that the application of lime is sometimes not enough. Here phosphate was needed. Left, lime alone; right, lime and acid phosphate, Bedford field, Ind. (Illustration supplied by the Purdue University Agricultural Experiment Station.)

by these States clover responds to phosphates, but the best results are secured where the lack of lime, if any, has first been made good.

POTASH.

Potash has not been found so generally lacking as phosphate, but there are sections, as well as special soils, on which potash is the limiting factor in red-clover growing. Potash has been found to increase clover yields in Delaware, Kentucky, New Jersey, and Wisconsin, while in Massachusetts clover can not be successfully grown without potash.[17] Where potash is needed it must be supplied, but the soils on which potash alone will determine the success or failure of clover are not common, though on many it will increase the crop.

[15] Roberts, George, and Ewan, A. E. Report on soil experiment fields. *In* Ky. Agr. Exp. Sta. Bul. 228, p. 85–120. 1920.

[16] Wiancko, A. T., and Jones, S. C. The value of phosphates on Indiana soils. Ind. Agr. Exp. Sta. Bul. 210, 16 p., 4 fig. 1918.

[17] Brooks, William P. Phosphates in Massachusetts agriculture. Mass. Agr. Exp. Sta. Bul. 162, p. 130-167, 2 pl. 1915.

Whether such increase will pay for the cost of the fertilizer is a question that can be settled only by trial in each case.

MANURE.

It is probably true that a liberal use of manure will do more to insure a good stand of clover than any other one thing. Dairy farms, where stable manure is abundant, are seldom troubled with clover failure. A good application of manure on many soils will enable the clover to grow even if the lime supply is not what it should be, and, of course, the manure carries certain amounts of phosphates and potash. In many of the experiments reported by the State agricultural experiment stations it was shown that manure alone usually insured a stand of clover, though often the addition of lime was beneficial. In some cases, however, manure alone has proved

FIG. 5.—Yields of red clover, showing that when the application of lime is needed, manure alone will not give maximum results. Left, clover from untreated plat; middle, from a plat treated with manure; right, from one treated with manure and lime. Francisco field, Ind. (Illustration supplied by Purdue University Agricultural Experiment Station.)

of no value, as was shown in the Kentucky work referred to above, as well as for other fields in the same State. On many of these fields manure alone had little or no effect, while in most cases the increase in yield with lime was striking. In some cases, however, a striking benefit from manure in addition to lime has been shown, as was the case on the Worthington field in Indiana,[18] where limed soil produced 5,420 pounds of clover hay, while lime plus manure produced 7,440 pounds. On this field both lime and manure gave fair yields, but the combination of the two gave the best results. The need of both lime and manure was also shown on the Francisco field in Indiana (fig. 5). The chief objection to stressing manure as a remedy for clover failure is the difficulty of getting a sufficient supply. On stock or dairy farms where manure is plentiful there

[18] Wiancko, A. T., and Jones, S. C. The value of manure on Indiana soils. Ind. Agr. Exp. Sta. Bul. 222, 20 p., 6 fig. 1918.

is little clover failure, but on general farms or on grain farms there is not enough manure to go around, and it can seldom be bought, even if it would pay to do so. When it can be had, however, its use on clover is advisable.

ORGANIC MATTER.

Organic matter is essential to a fertile soil. It serves various purposes—to provide food for beneficial microorganisms and through them to furnish food for crop plants; to loosen up stiff soils and to make loose ones more retentive of moisture.[19] So far as clover is concerned the lack of organic matter is felt most in stiff clays and silts. In the absence of organic matter these lose their friable condition and bake when dried. On such soils the young clover plants suffer and are easily killed by drought. When seeding is delayed the baking of the surface under a warm May sun may even prevent the seedlings from getting through the crust. On many soils in the clover belt the deficiency in organic matter is due entirely to constant unwise cropping. Where clover is kept in the rotation and where crop residues are not burned or wasted but are returned to the soil, the lack of organic matter will seldom be felt, and if it is felt it can be remedied by turning under a crop or two of green manure. Stable manure is, of course, the best farm source of organic matter, but there are few farms on which there is enough stable manure to supply all the fields. On grain farms especially the conservation of the organic matter in the way of crop residues is important. The roots of the crops, especially grass and clover if the growth is good, furnish a large amount of organic matter, and the growth of these roots can be greatly stimulated by the application of fertilizers. In red clover an especially large proportion of the total weight is in the roots. When the organic matter in a soil has once been exhausted there is no choice but to put it back in some way if clover is to be successful. The hard, baked soil will not permit young clover plants to thrive. There are ways in which this difficulty can be temporarily overcome. These are discussed on page 23.

LIMING.

FORM OF LIME AND FINENESS.

Any form of lime may be used provided the ground limestone is fine and it is remembered that, roughly, the active lime content of burnt lime, hydrated lime, and fine-ground limestone is about as 100, 75, and 50. In other words, 1,000 pounds of burnt lime, 1,500 of hydrated lime, and 2,000 of fine-ground limestone have about equal lime content. The degree of fineness necessary in lime has been studied by some agricultural experiment stations, especially by the Pennsylvania station. In general it has been found that the finer the limestone the better and quicker the effect. Excessively fine grinding is, however, too expensive, and a fineness of 80 to 100 mesh is

[19] Piper, C. V., and Pieters, A. J. Green manuring. U. S. Dept. Agr., Farmers' Bul. 1250, 45 p., 15 fig. 1922.

generally considered the most satisfactory. The more acid the soil the more difference will the degree of fineness make (fig. 6).

WHEN TO LIME.[20]

For lime to have the best effect it must be thoroughly mixed with the soil. This can be best done when the lime is spread on the plowed land and worked in by disking and harrowing. It should not be spread before plowing, as then it will not be present in the surface layer where it is needed. The Ohio station has secured good results from liming the cornland two years before clover. Others prefer to lime when preparing the land for grain. When no other method is possible the lime may be applied as a top-dressing to young clover provided very fine-ground limestone or dried marl is used, but this is the least satisfactory method. The best results have been had when the lime has been applied a year before clover is to be seeded. It then becomes well mixed with the surface soil.

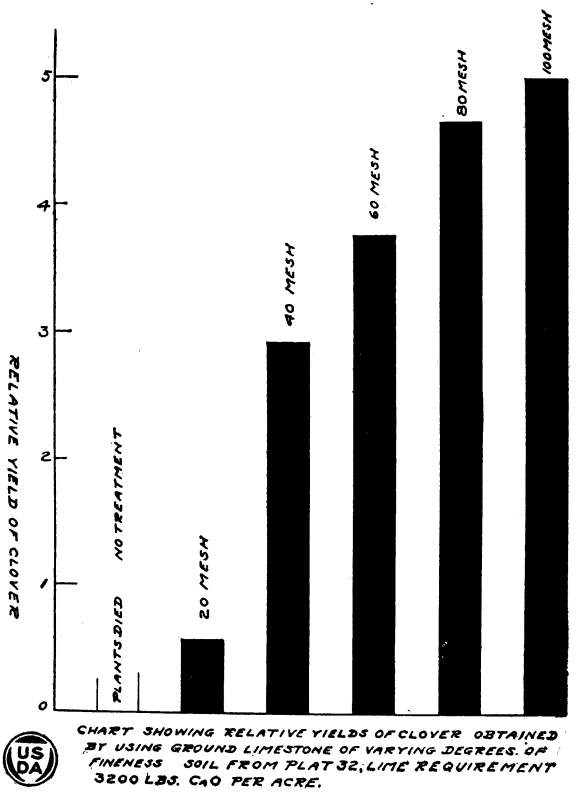

FIG. 6.—Diagram showing the relation between the fineness of ground limestone used and the growth of clover. (Pennsylvania Agricultural Experiment Station Report, 1912–13.)

PLANT INDICATORS FOR SOIL ACIDITY.

There are some plants that thrive so much better than red clover in an "acid" soil that they may be used as indicators to tell whether a soil is probably acid. The most common of these is sorrel, which while it will also grow in limed soil is crowded out by clover on such land, but on "acid" soil it becomes conspicuous. Dewberries, creeping thyme, sour dock, five-finger, and broom sedge are other common field weeds that do well on such soil, and when these are present in considerable abundance the soil is almost certainly acid. The poor growth of clover is in itself suspicious, though this may be due to lack of phosphate or some other element of fertility.

[20] Shorey, Edmund C. The principles of the liming of soils. U. S. Dept. Agr., Farmers' Bul. 921, 29 p., 5 fig. 1918.

CARE IN USING LIME.

A word of caution must be added about using lime. Though in itself a necessary plant food, it will not take the place of nitrogen, phosphoric acid, and potash. On soil where the lack of lime is the limiting factor the addition of lime may enable the clover to exhaust further the supplies of raw plant food, and thus in time the result will be a depleted soil. There is an old saying that "lime and lime without manure will make both farm and farmer poor," and this is as true to-day as it was a hundred years ago. The use of lime to get clover must be accompanied by proper farm practice in the matter of manure and fertilizers and in the turning under of organic matter. Otherwise, the last state of such a farm will be worse than the first.

SUMMARY OF SOIL CONDITIONS.

It has been shown that on many soils the application of lime, phosphates, and in some cases potash will result in a good crop

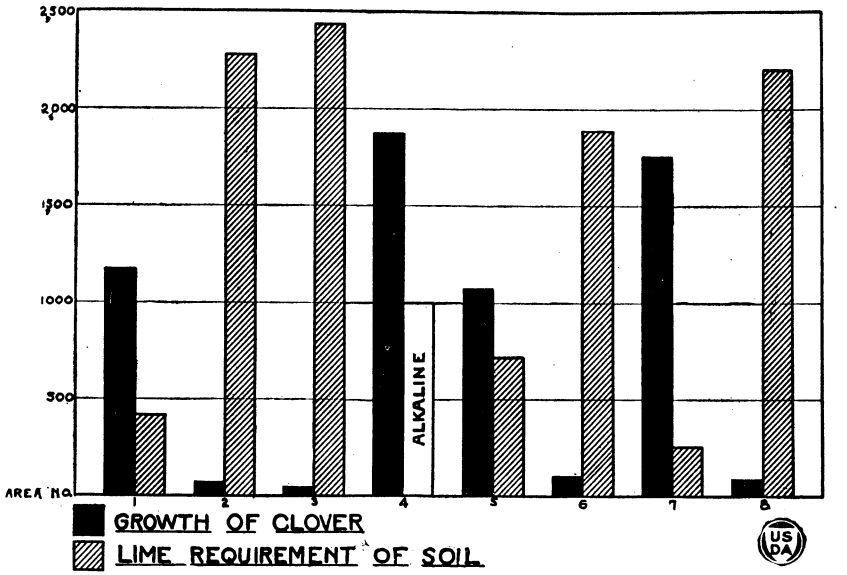

FIG. 7.—Diagram showing the relation between the lime requirement of soil and the growth of clover. (Pennsylvania Agricultural Experiment Station Annual Report, 1913–14.)

of red clover where without these elements clover fails or yields an unprofitable crop. It is not possible to state with any degree of exactness how much lime is needed on any soil to insure the growth of red clover. The Pennsylvania Agricultural Experiment Station has shown that clover did well on soils with a "lime requirement," as determined by chemical means of 500 to 1,000 pounds per acre. As the "lime requirement" increased, the clover grew weaker and finally ceased to grow [21] (fig. 7). In some experiments at the Wis-

[21] White, J. W. Concerning the growth and composition of clover and sorrel (Rumex acetosella) as influenced by varied amounts of limestone. *In* Pa. Agr. Exp. Sta. Ann. Rpt. 1913–14, p. 46-64, 12 pl. 1915.

consin station it was found that acid soil treated with half enough lime to satisfy the "lime requirement" gave nearly as good crops as that to which enough lime had been applied to fully satisfy the "lime requirement."[22] It is clear that a neutral or alkaline soil is not required and that the growth of the clover depends on other conditions as well as on the amount of lime in the soil. In New York State a field was found on which red clover was growing vigorously, though the "lime requirement" was 1,400 pounds per acre, but the owner of this field had put on 8 tons of stable manure and 500 pounds of acid phosphate per acre. Another field across the road had been limed, but had not received phosphate, and the stand of clover was poor. As already stated, the growth of a crop is an index of the sum total of conditions, favorable and unfavorable. The response of the crop is the final test of whether any element must be added to a given soil. While the results of the work of the various agricultural experiment stations will be applicable to many of the soils in the various States, there are very likely to be local conditions that may make it desirable for each farmer to test the effect of the various fertilizers on clover. Given a well-drained soil and an unsatisfactory clover crop, it may be fairly assumed that something is lacking and that when this lacking element is supplied good crops can be grown.

It should not be difficult for any farmer to tell what his fields need to grow good clover, although determining the exact quantity that will be most profitable may be a somewhat complicated undertaking. The accompanying diagram (fig. 8) shows a suggested arrangement of a test field. Such a test should answer the question whether that field needs lime or phosphate, either alone or in combination, and whether with or without manure. In order to make this as simple as possible potash has been left out, since potash is rarely the limiting factor over the main part of the clover belt, though its application may sometimes be profitable.

SEED, SEED BED, AND NURSE CROP.

A second group of factors that sometimes cause clover failure is the use of poor or nonadapted seed, or poor seed bed, and the nurse or companion crop.

SEED.

It should hardly be necessary to point out that clean, viable seed should be used. The matter of adaptability, however, is fully as important, is imperfectly understood, and a simple inspection of the seed sample gives no clue to its origin. Clover seed is regularly imported and exported, the volume of trade in either direction depending on crops and prices. Most of the seed that has been imported into the United States was produced in southern Europe, in Italy, or in southern and eastern France. There is no means of knowing where the imported seed is sold; though it has been known

[22] Fred, E. B., and Graul, E. J. The gain in nitrogen from growth of legumes on acid soils. Wis. Agr. Exp. Sta. Research Bul. 39, 42 p., illus. Literature cited, p. 41-42. 1916.

to be sold as far west as Indiana, it seems probable that most of it finds a market farther east. The plants produced from much of this imported seed are not adapted to American conditions, and the use of this seed is one cause of the failure of a good stand to survive the winter and produce a crop. Experiments carried on by the United States Department of Agriculture in cooperation with some of the State agricultural experiment stations have proved that plants grown from clover seed produced in Italy will usually not endure the winters in the Ohio River Valley, and independent studies in New York have shown the same to be true there. If the Italian clover plants are covered with a good depth of snow during the winter, they sometimes come through; but even then the crop is small. Plants produced from French and Chilean seed have usually survived the winters, and seed from these sources probably is not often responsible for direct failure. However, the French clover has commonly been inferior to American as a producer, and both French and Chilean clovers recover poorly after the first cutting and often make but a scanty second growth or none at all (fig. 9). The European red clovers are prevailingly smooth and so make a cleaner hay than American red clover, but the use of im-

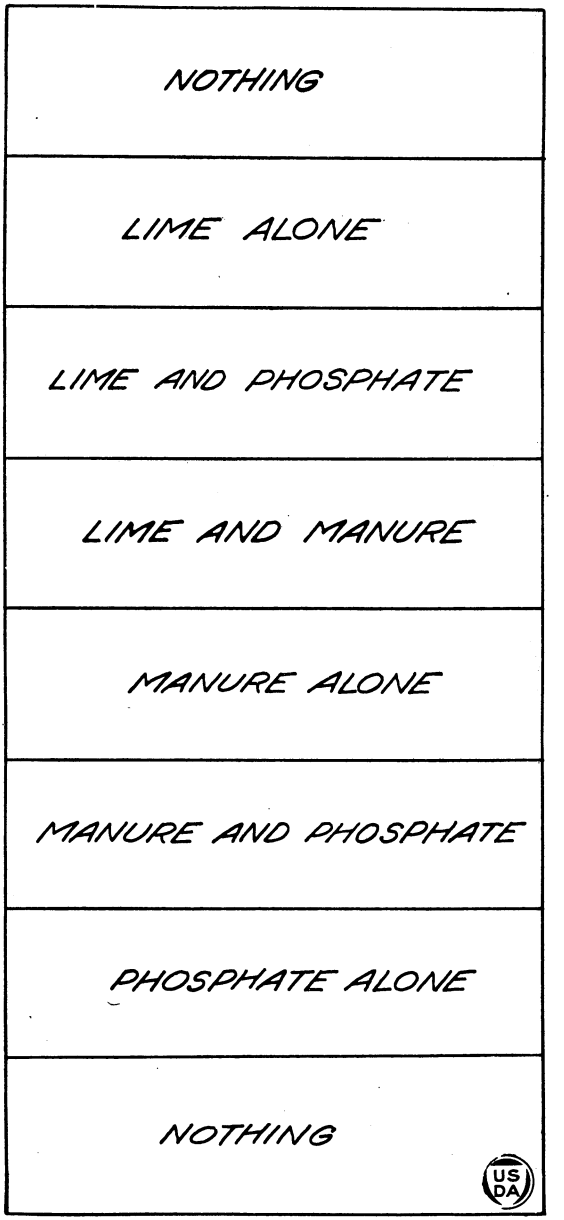

FIG. 8.—Outline of a simple experiment designed to enable a farmer to determine what his land needs in order to grow clover successfully.

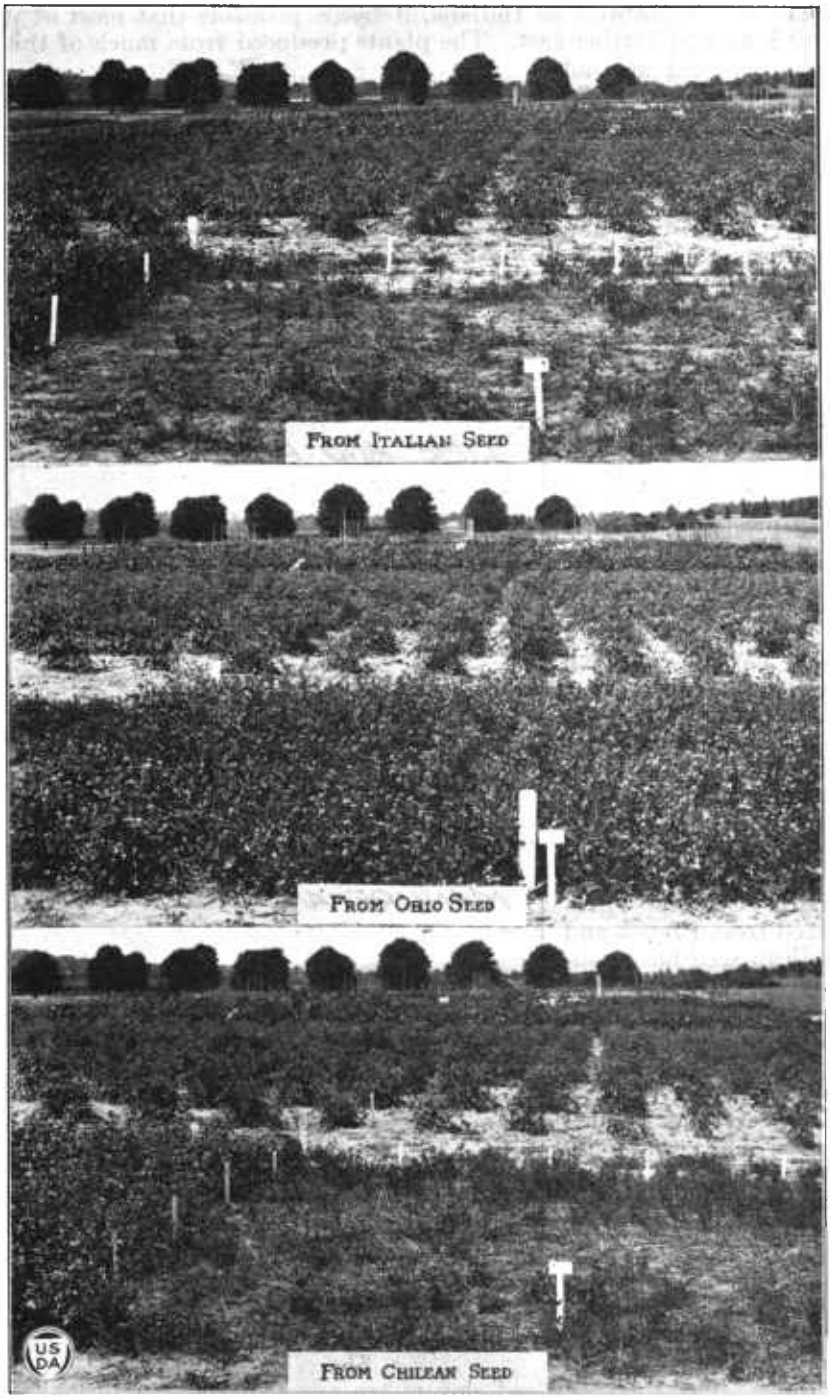

FIG. 9.—Second growth of clover on adjacent plats (foreground) at the Arlington Experiment Farm, Va. Photographed July 21, 1922. The first growth on the Chilean plat was as good as that from Ohio seed.

ported seed, especially that from Italy, is not advisable. Chilean and French seed can be used with better chances of success, though the second growth may often be of little value.

SEED BED.

Clover needs a good seed bed, fine on top but firm beneath. Sowing on freshly prepared ground without adequate packing is almost certain to result in failure. On ground that honeycombs with frost clover may be seeded very early in spring. In fact, other things being equal, early spring seeding is best, since clover enjoys cool, moist weather and if sown early gets ahead of summer weeds. On soil that bakes it is better to seed after the ground can be worked and then to harrow crosswise of the grain rows, or the clover may be seeded alone on a specially prepared seed bed at any time in the summer up to the middle of August in central Indiana and Ohio, but only on land that is not foul with weeds. On very weedy land clover seeded alone in early summer is quite sure to be crowded out by weeds. Sowing after grain harvest, where this can be done on a well-prepared seed bed after plowing the stubble, has the further advantage that plowing under the stubble helps to control the Hessian fly and the wheat jointworm, both of which live over in the stubble till ready to infest the new crop.

Seeding at various times and by various methods has been successful in different parts of the clover area. There is probably no one method that can be universally recommended. But whatever method is used, it should be one in which the seed can be put into a fine bed with solid ground beneath it. That is the all-important matter.

NURSE CROP.

No one will ever know how many failures are due to the nurse crop, a more appropriate name for which would be the "companion crop." Many observations have been made where clover has failed to make a stand when sown with a nurse crop while succeeding when seeded alone, but no systematic and comprehensive studies are on record. The Iowa Agricultural Experiment Station found that in 1910 50 per cent of the red-clover seedings in that State were lost; in 1911, 80 per cent; and in 1912, 35 per cent. While various causes are considered in a measure responsible, a very large part of the trouble is laid to the nurse crop, mostly oats.

The chief argument for seeding clover with a grain companion crop is to get the most possible out of the land. It is no doubt profitable to take off a grain crop and have a good stand of clover the same season, and where this can be done successfully the practice is a good one. It is necessary, however, to remember that the companion crop always has the advantage of the clover, since it is a more rapidly growing crop, and that on soils where fertility or moisture is not abundant the weaker plants must suffer. The presence of a companion crop on poor or droughty land is always a source of danger to the clover, and many failures are due to the competition of the grain crop. To minimize this danger it is wise to select the companion crop with a view to the good of the clover. In most cases winter wheat is the usual companion crop, and this is probably as

good as any, but even winter wheat or rye is often fatal to the clover. When clover is to be seeded with spring grain, barley should be chosen wherever possible, as it is less likely than oats to hurt the clover. If oats must be used an early variety should be selected, and only half to two-thirds the usual quantity of grain should be seeded. Further, if the season turns dry and the clover is to be saved, the oats or barley should be cut for hay rather than left to ripen. In general, it may be said that on fertile soil or in sections not subject to summer droughts a companion crop will not hurt the clover. On run-down soils or where the summers are dry every possible measure should be taken to minimize the danger to the clover from the companion crop. Such measures include a careful selection of the companion crop, adequate fertilizing, top-dressing with manure or mulching with straw, a thin seeding of the companion crop, and finally cutting this crop for hay rather than for grain.

INSECTS AND DISEASES.

The third group of causes to which failures may be attributed are insects and plant diseases. Data are lacking for any accurate estimates of the extent of the injury these pests may cause. So far as known, insects rarely cause what may properly be called clover failure, although cases have been reported where insects destroyed a crop. This is rare, however, and the only insect known to be a serious enemy to a clover stand is the root-borer.[23] This insect is widespread, but with rare exceptions it damages the clover only in the late summer of its second year. The presence of the borer renders it inadvisable to try to keep a clover field more than two years, as loss from this insect becomes too great after that time.

Although not an insect, the stem eelworm, or nematode, so destructive of red clover in England, may be mentioned here. This pest is troublesome on clover in America only in the Snake River Valley of Idaho, where on irrigated land it has caused some damage. Usually, however, this damage has fallen far short of failure, and at present this nematode can not be considered a factor in the problem. East of the Great Plains, in the main red-clover belt, it is not known to occur on red clover. Another eelworm, however, which causes root-knot, infests many soils in the South and has in West Virginia been reported to cause local failures.

Fungous diseases are more serious than nematodes in bringing about clover failure, and there is no doubt that some diseases have caused failure. This has been conspicuously the case in Tennessee, where a form of anthracnose is known to have caused extensive loss of clover stands since 1896, and doubtless much earlier. Anthracnose is widespread, occurring all through the Ohio Valley, in the Great Lakes region, and in the East, but only in the southern part of the clover belt has it been known to cause clover failure. Several European investigators have stated that clover raised from seed grown in southern Europe is more susceptible to anthracnose than that from northern Europe or from America. So far as studies of this matter have been carried on in the United States this view

[23] See Pieters, A. J., Red-clover culture, U. S. Dept. Agr., Farmers' Bul. 1339, 32 p., 21 fig. 1923.

has been confirmed. The Tennessee Agricultural Experiment Station has selected and introduced a variety of red clover resistant to the Tennessee form of anthracnose.

The stem-rot, that common cause of clover failure in England, occurs in the United States, having been reported from a number of States as far south as North Carolina. It also is found in Canada and in Oregon, in which State it is known to have caused local or partial failures. It also seems probable that some failures reported on fertile soils in North Carolina may have been due to this disease. In general, however, there is no evidence that stem-rot has caused much trouble in the main clover belt, though it is possible that this lack of evidence is due to imperfect data. A root-rot, the specific cause of which is still uncertain, causes not infrequent failures in Ohio and has also caused failures about Washington, D. C. Other diseases, such as leaf-spots, rusts, and mildew, cause some damage each year, but never enough to be called clover failure. The extent of the damage caused by the worst cases of these troubles is usually estimated at a maximum of 20 to 25 per cent.

The remedies for failures caused by fungous diseases are, first, proper liming and fertilizing of the soil. The Tennessee station learned that even where anthracnose was present the damage was much reduced when the land was limed. This merely means that by improving the soil conditions for the clover the plants were better able to resist the attack of the disease. The second and only other method of fighting these diseases is the substitution of some crop for clover, at least for a few years. Mammoth clover is less susceptible to most diseases than common red clover, and alsike clover is free from most of them. When neither of these crops is suitable, recourse must be had to an annual legume, such as soy beans.

WRONG TREATMENT IN THE AUTUMN OF THE FIRST SEASON.

Red clover can be killed by abuse quite as readily as any other crop, and the most common form of abuse to which it is subjected is overgrazing or cutting too late in the fall of the first year. No definite and comprehensive statement can be made as to how clover should be treated at that time, for so much depends on the season, the soil, and other conditions. It is a general principle, however, that where severe and perhaps snowless winters are likely to occur, clover should go into the winter with a fairly good growth, say six inches at least. If winds are likely to blow the snow away it is a good plan to cut the grain rather high, so as to leave a long stubble to hold the snow. In an average year clover can be grazed a little the first season, but this should be done with care, so that the plants are not fed down too closely just before cold weather. If the season is wet and unusually favorable the clover may bloom profusely. It is much better for the good of the next year's stand to clip those blooms early and so hold the clover back than to allow full growth and then take a hay crop. In some seasons and on good soils a hay crop may be taken safely, but it is always risky. The attempt to get too much out of the clover the first year is a common cause of loss of the clover by winterkilling.

NITROGEN-GATHERING BACTERIA.

It has been frequently suggested that one cause of clover failure is the absence of the bacteria that cause nodules on the roots of clover. Statements have appeared in responsible quarters that these bacteria will not thrive in acid soils and that hence clover will not do well in such soils. There is no experimental support for this notion, however, and the fact that alsike clover will be well supplied with nodules on such ground seems to make this explanation improbable. It is quite true that the nodule bacteria are essential, but they are so universally present throughout the clover belt that failure of clover due to their absence is extremely improbable. If on careful examination the clover that does grow is found not to have nodules, a limited supply of pure culture may be obtained from the United States Department of Agriculture and a trial readily made.[24]

SUBSTITUTION OF ANOTHER CROP.

On grain farms especially, mammoth clover may well be substituted for medium red clover and cut for seed, the straw going back on the land to maintain the organic matter in the soil. Mammoth clover can also be used with timothy, as it is ready to cut with that crop. The substitution of mammoth or alsike clover may also be the cheapest and at least temporarily the best plan in cases where lime must be added for medium red clover and where its addition is economically unwise or impossible. The practice of mixing alsike-clover seed with red clover when seeding is a good one. The alsike will catch on the poor spots or on the wet ones and thus help insure a clover crop over an entire field which would otherwise be spotted. No general statement can be made as to how much a farmer can afford to pay for lime and make a profit. That will depend so much on the crops produced, prices, and so on that any figures would be worse than useless. It is clear, however, that lime may cost too much to warrant its use, or the farmer may not have the money even if it would pay to spend it. In such cases it is better to fall back on mammoth or on alsike clover, as these will make some return, while sowing medium red clover would be only so much waste. It should not be forgotten, however, that soils do not need to be absolutely neutral to produce a fair crop of red clover. Often a smaller quantity of lime than would be necessary to satisfy the theoretical "lime requirement" of the soil will suffice to make the difference between a fair clover crop and a failure. This will be especially the case where injury from the companion crop is avoided or where the grain has been adequately fertilized with phosphate, which can also be utilized by the clover. A heavy application of phosphate to the wheat may often enable the clover to grow in spite of the lack of plenty of lime. As already stated, on land that can not be economically drained alsike clover should be grown. Where for any reason no clovers can be used winter vetch seeded alone or with rye may make a good substitute both as a producer of hay and as a soil improver.[25]

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[24] Address the Office of Soil Bacteriology, Bureau of Plant Industry, United States Department of Agriculture.

[25] Piper, C. V., and McKee, Roland. Vetches. U. S. Dept. Agr., Farmers' Bul. 515, 28 p., 10 fig. 1912; rev., 1923.

Where clover failure is due to loss of organic matter from the soil, or to lack of phosphates, or indeed to any cause except lack of lime, sweet clover may often be substituted to advantage and the soil restored to a condition where red clover will grow. Sweet clover is even more sensitive to the lack of lime than red clover, but with that exception will grow and make a fair crop on the most unpromising soils. It is already being extensively substituted for red clover in the West and Northwest. Unfortunately, most of the clover failures occur on soils deficient in lime, and on these the results with sweet clover will be equally unsatisfactory.[26]

Soy beans or cowpeas may also be grown for hay or soil improvement, but it must be noted that when these crops are cut for hay there is no benefit to the soil. Hogging down the crop is better, or in the case of soy beans the grain may be taken provided the straw is put back on the land and turned under as a crop residue.[27]

TEMPORARY EXPEDIENTS.

Besides the substitution of some crop for red clover, which should generally be regarded as a temporary expedient, other measures may be taken to get and hold a stand of clover where it commonly fails. The best of these, which perhaps should not be called an expedient, since it is a commendable practice at any time, is to top-dress with manure the wheat on which clover is to be seeded. This top-dressing is applied soon after the wheat is seeded and is one of the best methods to help out the clover on land where the chances would otherwise be against it.

A genuine expedient, however, is one that has been reported in use both in Kentucky and in Ohio.[28] This is to spread straw over the wheat field before the wheat is up. The clover is broadcasted early the next spring. The straw makes a mulch which tends to hold the moisture and to protect the germinating clover plants in early spring. While it is advisable to use this or any other expedient that will insure a catch of clover, it may be pointed out that the straw mulch merely serves one purpose, that of holding the moisture and keeping the soil from baking, which would also be served by a good supply of organic matter in the soil. As an expedient the practice is valuable, but the need of resorting to such an expedient should awaken the owner of the land to the necessity of getting organic matter into his soil.

SUMMARY AND SUGGESTIONS.

The entire or partial failure of red clover has been shown to be due to a number of causes working together or separately. The most important of these, in that they are the most common and widespread, are due in large measure to continued unwise farm practices and can be remedied only by changing those practices. A run-

[26] See Coe, H. S. Sweet clover: Growing the crop. U. S. Dept. Agr., Farmers' Bul. 797, 34 p., 11 fig. 1917. Drake, J. A., and Rundles, J. C. Sweet clover on corn-belt farms. U. S. Dept. Agr., Farmers' Bul. 1005, 28 p., 9 fig. 1919.

[27] Morse, W. J. The soy bean: Its culture and uses. U. S. Dept. Agr., Farmers' Bul. 973, 32 p., 15 fig. 1918.

[28] Drake, J. A. The management of clover in corn-belt rotations. Ohio Agr. Exp. Sta. Cir. 111, 19 p., 4 fig. 1911.

down soil is an abused soil. In most cases such a soil can be restored to a reasonable fertility by reversing the process to which its condition is due. Instead of the organic matter being exhausted by constant cropping, it must be restored either by farm manure or by green manure; instead of the natural supplies of lime, phosphate, and potash, which may have been scanty in the first place, being further drawn on, these elements must be added to the soil. The evidence from all sources is overwhelming to show that where this is done clover can be successfully grown again. With good clover crops better crops of corn and grain inevitably follow.

Where clover failure is experienced or crops of clover are unsatisfactory the first step should be to look after the drainage. If the land is not well drained and as a consequence the clover heaves badly in spring, the drainage must be improved or all other efforts will be wasted. If the conditions are such that the drainage can not be economically improved, alsike clover should be substituted for red clover. There is no use trying to grow red clover on badly drained land. In very favorable seasons there may be an occasional good crop, but generally most or all of the clover will die before spring. Alsike clover, while not as heavy a cropper as red clover because it does not commonly yield two cuttings, will usually make a fair to good crop on such soil.

Where drainage is good and clover is unhealthy or fails, the first step should be to consult with the county agricultural agent or with the State agricultural extension service. In many cases the station workers will know whether the soils in that section need lime or some fertilizer, and the remedy can be applied at once. Where no certain information is available a simple trial will soon tell the story of what clover needs to thrive on that particular farm. Proper consideration should be given to the preparation of the seed bed, time of seeding, and the companion crop. The practice in regard to the last two will vary, but generally where failure is thought to be due to the companion crop a radical change in practice should be made. Clover should be seeded alone, a less damaging companion crop should be selected, or it should be seeded at a less rate or should be cut for hay instead of for grain.

Where a specific disease is found to be causing failure, there is nothing to do but to substitute some other crop for clover except where a resistant strain of clover has been developed and its seed is available. In such case the disease-resistant strain should by all means be used.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE.

January 9, 1924.

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Director of Regulatory Work	WALTER G. CAMPBELL.
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